Contract Number No.
W9132T-04-C-0012

City of Mesa

Midpoint Project Description Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Arizona National Guard Armory
615 N. Center Street
Mesa, Arizona. 85201

June 16, 2005

Executive Summary

The City of Mesa Gas Division in partnership with the Arizona Army National Guard (AZARNG) has received a contract award from the US Army Corps of Engineers Construction Engineering Research Lab (CERL) to test a Proton Exchange Membrane (PEM) fuel cell. As part of the FY'03 PEM Demonstration Program managed by CERL, the City of Mesa will engage in a progressive PEM fuel cell demonstration project for a period of one year. This PEM demonstration is now operational following the initial start-up on May 12, 2005.

The Mesa Service Battalion Armory located adjacent to the Chicago Cubs training center at 615 N. Center Street, Mesa, Arizona is the demonstration site for the project. The fuel cell located at the building is a GenSys™ 5CS 5kW unit manufactured by Plug Power Corporation, Latham, NY. The City of Mesa will operate the unit in the grid parallel configuration at 2.5 kW for the one-year demonstration. The fuel cell has the following monitoring equipment; a gas meter, a btu meter, and a bi-directional electric meter. The fuel cell is also equipped with a phone line that automatically signals an alarm if an event or failure of the fuel cell occurs.

The thermal energy produced by the unit will generate domestic hot water for the building's use throughout the one-year of operation. The total estimated energy savings of the fuel cell project is expected to be $2,500.00 annually.

During the evaluation, Mr. Harry Jones, the Special Project Coordinator for the Gas Division will act as the host point of contact for the demonstration project. Mr. Jones can be reached at (480) 644-4496 or by email at Harry.Jones@cityofmesa.org

Table of Contents

Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

PEM Fuel Cell demonstration at Mesa Service Battalion Armory, Arizona Army National Guard, Mesa, Arizona.

2.0 Name, Address and Related Company Information

City of Mesa Gas Division
640 N. Mesa Drive.
Mesa, Arizona. 85201
(480) 644–2137

DUNS# 02-014-1404
CAGE#
TIN# 86-6000-252

The City of Mesa is a municipal organization providing water, gas, and electric utility services.

3.0 Production Capability of the Manufacturer

Plug Power has been in design and production of PEM fuel cell systems since its inception in 1997. The GenSys™ is manufactured at Plug Power's Latham, New York manufacturing facility. The facility is 50,000 square feet dedicated to fuel cell production and includes a testing facility with approximately 100 employees. With the current staff, Plug Power's production capability is five systems per week with the ability to significantly increase production.

4.0 Principal Investigator(s)

Gerald Paulus
Gas Division Director
City of Mesa
(480) 644-2872
(480) 644-3336
Gerald.Paulus@cityofmesa.org

Jeff Seaton
Energy Manager
Energy Engineering Specialist
Energy Manager
The Arizona Army National Guard
State of Arizona – DEMA
(602) 267-2743
jeff.seaton@az.ngb.army.mil

5.0 Authorized Negotiator(s)

Harry Jones
Special Projects Coordinator
City of Mesa
(480) 644-2137
(480) 644-5236
Harry.Jones@cityofmesa.org

6.0 Past Relevant Performance Information

Over a span of four years, the City of Mesa Gas Division and the Arizona National Guard have been involved in numerous successful distributed generation projects. The electrical production capability of these projects exceeds 628 kW. Throughout this time period, the Gas Division remained in the installation, maintenance, and repair of fuel cells.

Previous distributed generation projects include:

- The environmental office building located at the Arizona National Guard ECO Building, 5636 E. McDowell Road Phoenix, AZ. 58008-3495. This project site has evolved since 1997 and today is truly a self-sustained office structure, powered by twelve kilowatts of photovoltaic arrays and twelve hundred watts of wind turbines. Currently, six kilowatts of additional photovoltaic modules are being added to the ECO Building. Since 1997, Jeff Seaton has been involved in multiple distributed generation projects at this site. He is the Energy Engineering Specialist for Department of Emergency and Military Affairs (DEMA) Facilities Management with the Arizona Army National Guard. His contact number is (602) 267-2643.

- A 10kW, grid connected wind turbine at Camp Navajo Training Site in Bellemont, Arizona. Awarded in 2001, it is a $70,000 distributed generation project made possible through a very successful partnership with the Army National Guard and the City of Mesa, Gas Division, and funding from DoD - National Guard Bureau. The point of contact for the project was Jeff Seaton, Energy Engineering Specialist for DEMA Facilities Management with the Arizona Army National Guard. His contact number is (602) 267-2643.

- The DG project, which installed two 200 kW fuel cells at the Western Army Aviation Training Site (WAATS) in Marana, Arizona. Awarded in 2000, the Gas Division was allotted $200,000 for the purchase, installation, and operation of this fuel cell. Three, 200kW phosphoric acid fuel cells were relocated from previous DoD fuel cell projects. These three fuel cells were transported to the WAATS complex for installation. After salvaging parts and making repairs between the units, two units were installed at the Combat Mission Simulator Complex at the Western Army Aviation Training Site and supplied premium power for the critical operation of this facility. The City of Mesa operated these fuel cells for almost nine months. The project received over 90,000 kWh of energy produced from the fuel cell installation. When the serving utility made arrangements to provide a secondary grid feed to the facility, the units were no longer needed and were retired. Together the City of Mesa and the AZARNG gained great experience and benefited from the project. The point of contact for this project was Jeff Seaton, Energy Engineering Specialist for DEMA Facilities Management with the Arizona Army National Guard. His contact number is (602) 267-2643.

- The installation of a 200 kW fuel cell at the City of Mesa, which was installed at the Utilities Building. Awarded in 1999, this $800,000 project continues to provide electricity and thermal energy to the building during the day and electricity to the grid at night. The thermal energy is provided to the absorption chiller to cool the building and to provide domestic hot water. Thermal energy is also provided for heating the building during the winter months. This fuel cell has been operating successfully and efficiently for three years. For this project, the point of contact is Gerald Paulus, City of Mesa Gas Division Director. His contact number is (480) 644-2872.

The AZARNG and the City of Mesa have extensive experience in the field of distributed generation. In addition to the agencies individual track records, they have successfully partnered on the installation and maintenance of fuel cells and wind turbine distributed generation projects in the past. These agencies are uniquely qualified to make this 5kW PEM Fuel Cell demonstration project a success for everyone.

7.0 Host Facility Information

The Mesa Service Battalion Armory is an Army post located adjacent to the Chicago Cubs winter training site just two miles north of downtown Mesa. This centrally located facility is currently home to the 1-180 Field Artillery (FA), a M109A5 howitzer battalion in direct support of the 11th Armored Cavalry Regiment. The City of Mesa is the provider of gas, electric, water, and wastewater utilities to the site.

8.0 Fuel Cell Installation

The Mesa National Guard Armory main building was the selected location for the installation. The fuel cell was set on the southwest end of the building next to the building's electrical utility box. Figure 1 & 2; show the fuel cell sitting on its pad. This location puts the fuel cell within a 10ft radius of domestic water, electrical, and natural gas connections. Just beyond the south wall are the showers, restrooms and the mechanical room. Figure 1 shows the proximity of the fuel cell to all needed utilities.

The City of Mesa used an outside contractor for the installation and worked closely with the Arizona National Guard to insure a smooth install. Work started on February 9, 2005, costing a

total of $81,092.62. No permits were required or issued for the site. The start-up of the unit happened on May 12, 2005, and required a total of 419 man-hours to commissioning.

There were many challenges to getting the unit up and running, mostly dealing with the inverter and batteries. On the first attempt to start the fuel cell, the inverter refused to go into a charging mode under any circumstance. Without the ability to recharge the batteries, the fuel cell would shutdown before completing start-up. Plug sent out a refurbished unit once, but it was determined to be a failed inverter. Battery failure was another challenge during start-up. This caused phantom faults with other systems due to being underpowered during start-up. One battery was replaced under warranty and the remaining three batteries were charged to correct the problem.

Figure 1

Figure 2

9.0 Electrical System

The fuel cell inverter has a power output of 110/120 VAC at 60 Hz, which is connected into one leg of the 240 VAC building distribution panel, located on the Southwest side of the building. The installation includes both a grid parallel and a grid independent configuration, see figure 3. The unit provides stand-by power to a new 100amp critical load panel, serving several plug loads within the building.

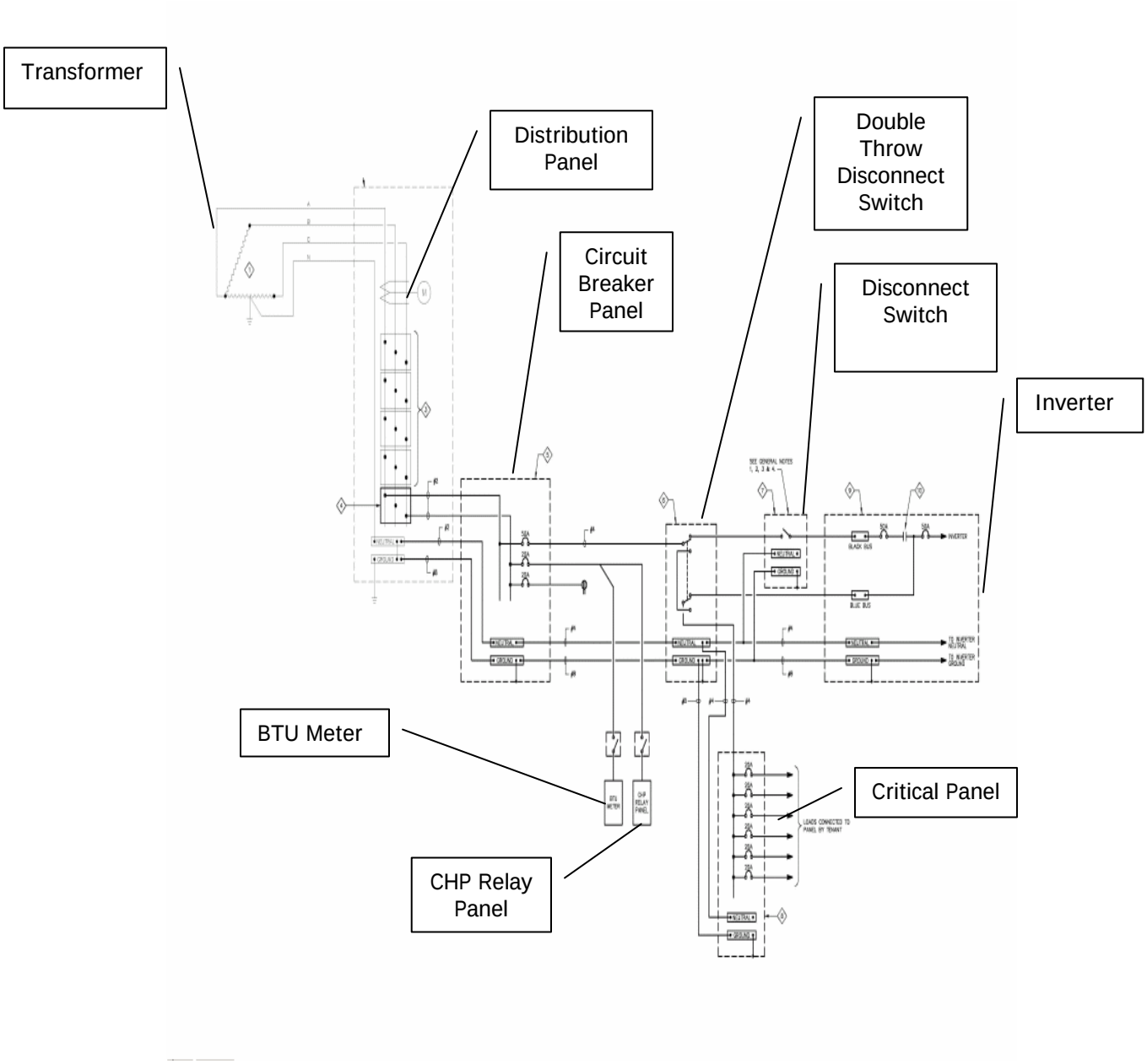

Figure 3

To meet the need of the electric utility, two 120 vac conductors were ran from the fuel cell. The grid parallel conductor runs through a single pole disconnect switch then to the main two pole disconnect before terminating at the main service panel. The secondary disconnect is an isolator from the grid for the electric utility. The second 120 vac conductor is the critical load feed. Power from this conductor feeds through the main two pole disconnect and on to the critical load panel. The critical load panel has various appliances throughout the building that are connected on 20 amps circuit breakers. A bi-directional meter was also installed to monitor any power distributed to the grid. Figure 4, below, is a photo of the unit on its pad showing the electrical interface on the building wall at right.

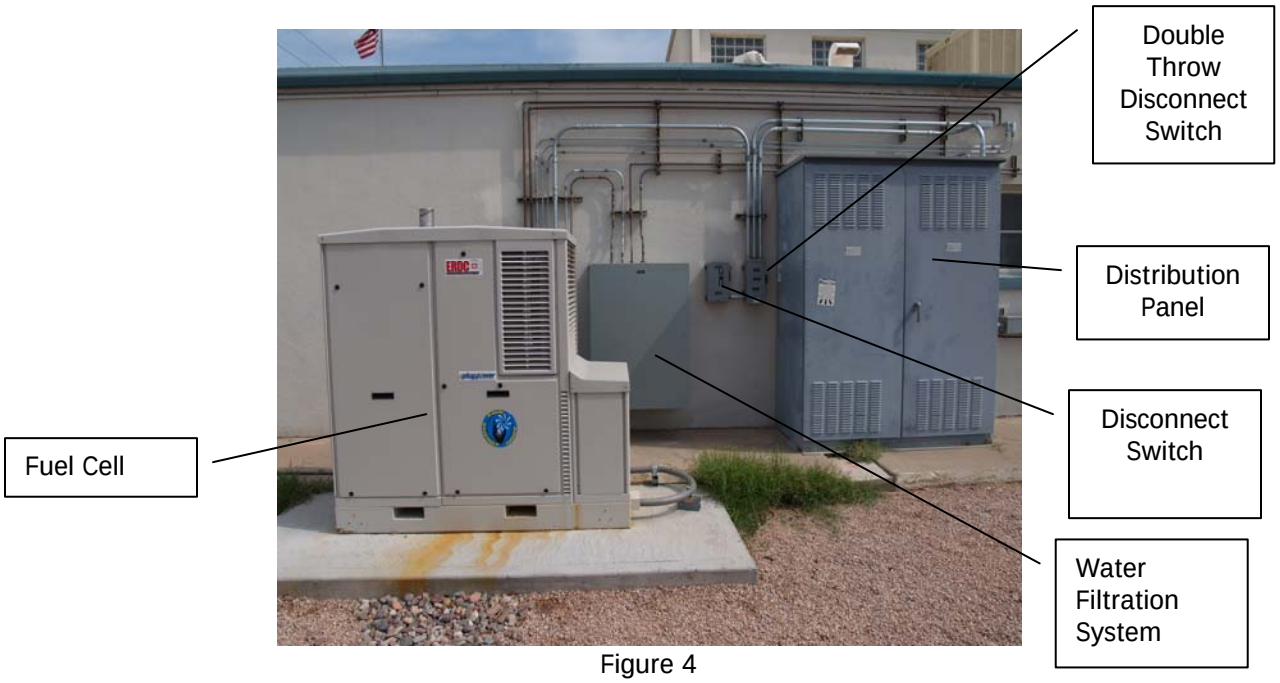

Figure 4

10.0 Thermal Recovery System

When operated at 2.5kWh, the fuel cell can generate waste heat at the rate of 8000 Btu/h for heating water. The thermal recovery system is set up for continuous of the primary and secondary heating loops. The primary loop uses a small pump to circulate 140 degree F water between the fuel cell heat exchanger and an external heat exchanger. There are approximately 30 feet of piping that runs between the fuel cell heat exchanger and the external heat exchanger. The external heat exchanger, located in the Guard's mechanical room, makes up the secondary loop, preheating the building supply water before sending it on to the facility's hot water tank. Component location of the thermal recovery system can be seen in figures 5 and 6, below. There is also an Onicon BTU meter (figure 5) which records the amount of thermal heat transferred to the building.

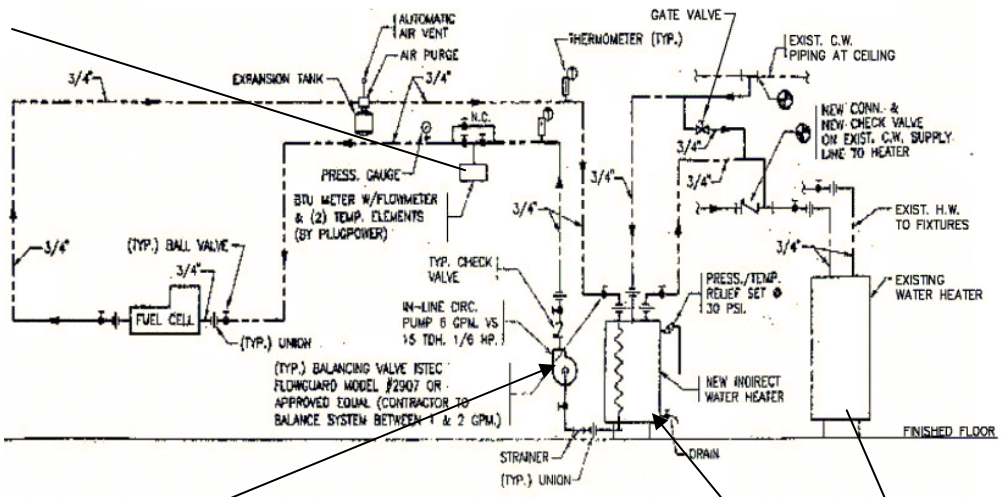

Figure 5

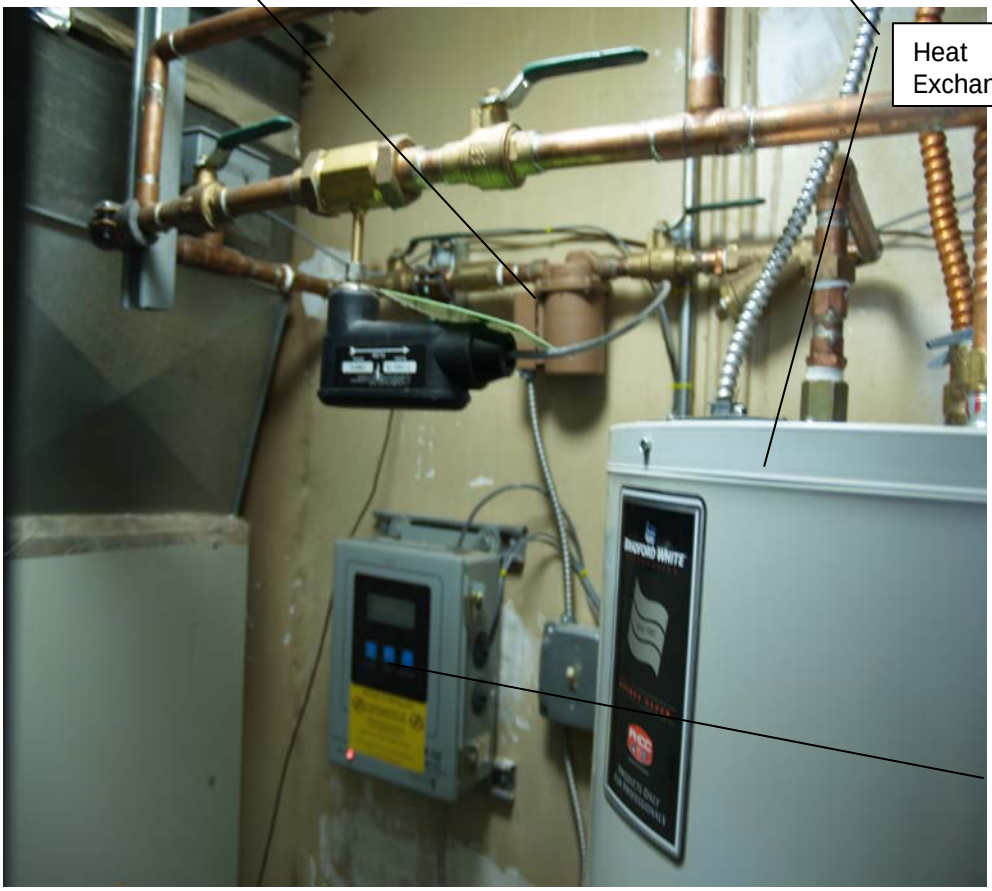

Figure 6

11.0 Data Acquisition System

There are two systems being used to monitor the fuel cell. Those systems are the System and Reformer Controller (SARC) and the SmartSignal predictive maintenance diagnostics technology. Monitoring and recording of fuel cell operations are performed by the SARC. This is an integrated part of the fuel cell requiring a dedicated phone line for communication. The dial tone is carried to the unit via a cat 5e twisted & shielded cable with a RJ11 jack to plug into the fuel cell. Monitored parameter conditions known as E-stop as well as other abnormalities are observed by the SARC. An E-stop can be any of the following conditions. Loss of communication of the SARC and inverter, cathode air flow falls too low, high natural gas pressure, methane and/or hydrogen gas leaks, cooling loss to electronic controls, loss of cabinet pressure, high cabinet temperatures, and humidifier overpressure. If the SARC detects any E- Stop or abnormalities, it will immediately shut down the unit and notify Plug Power. Once this notification is made, Plug Power will notify City of Mesa personnel by email.

The second system of monitored control is the SmartSignal predictive technology system. This system monitors the fuel cell for proper operation through a predictive algorithm. It is designed to look at the fuel cell in much the same way as the SARC does, by monitoring fuel cell sensors for abnormal changes. Where it differs from the SARC is in the degree of focus given to the sensor output. Gradual changes in sensor output are more closely monitored and applied to the predictive algorithm to predict failures. In doing this, it allows for early warning of impending abnormalities or potential failures and issues an alert in plenty of time to take corrective action. The goal of this technology is to avoid costly shutdowns, outages, equipment failures, missed opportunities, or other costly emergencies. All information is provided in a Windows format with "drill down screens" designed to pinpoint potential problems or failing equipment within the fuel cell.

12.0 Fuel Supply System

Natural gas service for the fuel cell was located next to the original gas meter. The service was split for building and fuel cell use. A separate natural gas meter illustrated in Figure 6 was provided as a means of consumption verification. To maintain the correct operating pressure of 7 inches water column (IWC), the service was provided with its own regulator at the meter.

Figure 6

13.0 Installation Costs

Direct Material		
	Fuel Cells	$70,000.00
	Materials	$14,340.75
	Travel &Training	$9,705.57
	Postage	$3,852.18
Service and Maintenance Parts		
Installation and Interconnection		
	Engineering	$13,886.53
	Installation	$41,909.23
Total		$153,694.26

14.0 Acceptance Test

The fuel cell was prepared and started in accordance with the manufacture's recommendations. A City of Mesa technician preformed all required tests during initial startup. A 48-hour acceptance test was also performed on the unit starting on May 12, 2005. The unit has been successfully running since the dedication ceremony. Please see appendix 2 for documentation of the test done by the technician.

Appendix

Appendix 1 - Monthly Performance Data
Appendix 2 - Documentation of Acceptance Test

System Number: SU01B000000314
Site Name:
Fuel Type: Natural Gas
Low Heating Value:
Capacity kW 5

Commission Date: 5/16/2005
Fuel Cell Type: GenSys 5CS
Maintenance Contractor:
Local Residential Fuel Cost per Therm: $/Therm
Local Residential Electricity Cost per kWhr: $/kWhr

Site Location(City,State):
Local Base Fuel Cost per Therm: $/Therm
Local Base Electricity Cost per kWhr: $/kWhr

Month	Run Time (Hours)	Time in Period (Hours)	Availability (%)	Energy Produced (kWe-hrs AC)	Output Setting (kW)	Average Output (kW)	Capacity Factor (%)	Fuel Usage, LHV (KW)	Fuel Usage, LHV (BTUs)	Fuel Usage (SCF)	Electrical Efficiency (%)	Thermal Heat Recovery (BTUs)	Heat Recovery Rate (BTUs/hour)	Thermal Efficiency (%)	Overall Efficiency (%)	Number of Scheduled Outages	Scheduled Outage Hours	Number of Unscheduled Outages	Unscheduled Outage Hours
insert month	*insert operating hours*	*insert hours in month*	*1	*insert produced energy*	*insert output setting*	*2	*3	*insert fuel consumption*		*insert fuel consumption*	*4	*insert heat recovery*	*5	*6	*7	*insert value*	*insert value*	*insert value*	*insert value*
July, 2005	744	744	100%	1859.84	2.5	2.50	50.00%	7486.35	2.56E+07		24.84%		0	0.00%	24.84%	0	0	0	0
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Running Totals																			
	Total Run Time	**Total Hours in Period**	**Total Availability (*8)**	**Total Energy Produced**	**Average Output Setting**	**Total Average Output (*9)**	**Total Capacity Factor (*10)**	**Total Fuel Usage**		**Total Fuel Usage**	**Average Electrical Efficiency (*11)**	**Total Thermal Heat Recovery**	**Average Heat Recovery Rate (*12)**	**Average Thermal Efficiency (*13)**	**Average Overall Efficiency (*14)**	**Total Outages**	**Total Hours**	**Total Outages**	**Total Hours**
	744	744	100%	1859.84	2.50	2.50	50.00%	7.49E+03	2.56E+07	0	24.84%	0	0	0.00%	24.84%	0	0	0	0

*1	Availability	=	Run Time / Time in Period
*2	Average Output	=	Energy Produced / Run Time
*3	Capacity Factor	=	Energy Produced / (Capacity * Time in Period)
*4	Electrical Efficiency	=	(Total Energy Produced * 3414 BTUs/kW-hr) / Total Fuel Usage
*5	Heat Recovery Rate	=	Thermal Heat Recovery / Run Time
*6	Thermal Efficiency	=	Thermal Heat Recovery / Total Fuel Usage
*7	Overall Efficiency	=	Electrical Efficiency + Thermal Efficiency
*8	Total Availability	=	Sum Total Run Time / Sum Total Hours in Period
*9	Total Average Output	=	Total Energy Produced / Total Run Time
*10	Total Capacity Factor	=	Total Energy Produced / (Capacity * Total Hours in Period)
*11	Avg. Electrical Efficiency	=	(Total energy produced * 3414 BTUs/kWh) / Total Fuel Usage
*12	Avg. Heat Recovery Rate	=	Total Thermal Heat Recovery / Total Run Time
*13	Avg. Thermal Efficiency	=	Total Thermal Heat Recovery / Total Fuel Usage
*14	Avg. Overall Efficiency	=	Avg. Electrical Efficiency + Avg. Thermal Efficiency

Appendix 1

Appendix 2 – Acceptance Test

Manual Test

1. Verify fuel cell disconnect switches:

    - Isolate grid power - OK
    - Isolate fuel cell power – OK
    - Isolate building's critical load panel and breaker panel - OK

2. Verify that the Inverter:

    - Senses grid power - OK
    - Senses battery voltage and charges - OK
    - Performs trip setting as outlined by manufacturer - OK